Removal of Heavy Metals from Waste Water Using Water Hyacinth

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***Abstract*— Water pollution has become one of the most serious problems of today's civilization. In the last few years considerable amount of research has been done on the potential of aquatic macrophytes for pollutant removal or even as bio-indicators for heavy metals in aquatic ecosystems. Water hyacinth is one of the aquatic plant species successfully used for wastewater treatment. It is very efficient in removing pollutants like suspended solids, *BOD*, organic matter, heavy metals and pathogens. This paper mainly focuses on the treatment of waste water using the plant 'water hyacinth' and has given emphasis to the removal of heavy metals by the plant. Water hyacinth' could grow in sewage; they absorb and digest the pollutants in wastewater, thus converting sewage effluents to relatively clean water. Thus, the plants hold promise as a natural water purification system, which could be established at a fraction of the cost of a conventional sewage treatment facility. The study conducted in this regard revealed how efficiently wastewater could be treated using the plant 'Water hyacinth'.**

***Index Terms*— macrophytes, absorption , adsorption, heliophytes, phytoextraction, bioaccumulators.**

I. Introduction

Water scarcity has been increasing all over the world and in many countries may become absolute by the year 2025 "Ref. [17]". This problem becomes more apprehensive when recognizing that the severity of surface water pollution is a worldwide problem "Ref. [18]". To tackle the problem, several measures for sustainable water resource utilization have been developed, of which wastewater reclamation and reuse is currently one of the top priorities "Ref. [14]". It was reported that domestic and Industrial discharges are probably the two most important anthropogenic sources for metals in the water environment "Ref. [4]".

The presence of heavy metals in water are toxic even at very low concentrations "Ref. [7]". Pollution of the biosphere with toxic metals has accelerated dramatically since the beginning of the industrial revolution. Water hyacinth (Eichhornia *crassipes*) an aquatic plant which could successfully used for removing various pollutants from water thus has great importance in wastewater treatment. It has a huge potential for removal of the vast range of pollutants from wastewater "Ref. [3]".

II. Research Significance

In this paper the main focus was on studying the efficiency of water hyacinth in removing dissolved solids, *B.O.D*, heavy metals mainly chromium and copper from the waste water, and the effect of the growth of water hyacinth on the pH of the waste water. To achieve this objective, water hyacinth was grown in synthetic wastewater prepared by adding varying concentrate ions of *Cr* and *Cu*. The concentrations of heavy metals, *pH*, *B.O.D* and total dissolved solids were noted in the waste water before and after cultivating water hyacinth and compared the results with the standard values.

III. Literature Review

Wastewater could be any water that has been adversely affected in quality by anthropogenic influence. It comprises liquid waste discharged by domestic residences, commercial properties, industry, and agriculture and can encompass a wide range of potential contaminants and concentrations "Ref. [9]". Treated wastewater can be reused as drinking water, in industry and in the rehabilitation of natural ecosystems "Ref. [15]". Although the nature has a fantastic capacity to deal with waste water and even pollution, with billions of gallons of polluted and dirty water, it cannot do the work alone. There are many technologies for wastewater treatment that can help in re-establishing and preserving physical, chemical and biological integrity of water. But the efficient and ecofriendly methods lacked in this regard

A. Water Hyacinth

Water hyacinth (*E.crassipes.*) is a fast growing perennial aquatic macrophyte and its name Eichhornia was derived from well known 19th century Prussian politician J.A.F. Eichhorn "Ref. [8]". It is well known for its reproduction potential and the plant can double its population in only twelve days. Water hyacinth is also known for its ability to grow in severe polluted waters. *E.crassipes* is well studied as an aquatic plant that can improve the effluent quality from oxidation ponds and as a main component of one integrated advanced system for the treatment of municipal, agricultural and industrial waste waters "Ref. [6]".

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Taxonomy

Division: *Magnoliophyta*
Class: *Liliopsida*
Subclass: *Commeinidae*
Super order: *Commelinanae*
Order: *Pontederiales*
Family: *Pontederiaceae*
Genus: *Eichhornia*

Morphology

Water hyacinth is an aquatic vascular plant with rounded, upright and shiny green leaves and lavender flowers similar to orchids. Individual rosette is erect and free floating with numerous stolons. Each one carries six to eight spirally arranged succulent leaves that are produced sequentially on a short vertical stem. Petioles are bulbous and spongy with many air spaces which allow plants to float on a water surface "Ref. [6]".

Top petal has gold yellow spot bordered with blue line. Root system of water hyacinth is dark blue in colour with numerous stolons. New plants are formed at the end of these stolons. Measured from flower top to root top *E. crassipes* usually reach the height of 1.5m and more. When grown in wastewaters water hyacinth is smaller and it often reaches heights no more than 0.5 to 1.2m. Growth of water hyacinth is primarily dependant on the ability of the plant to use solar energy, nutrient composition of water, culture methods and environmental factors. Plant growth is described in two ways, firstly, by reporting the percentage of water surface covered of a period of time and second and more useful method is by reporting the plant density in units of wet plant mass per unit of surface area.

This aquatic plant reproduced in both generative and vegetative ways. That means new plants could be produced from seeds or they represent clones derived from stolon elongation due to division of auxiliary meristems of mother plant.

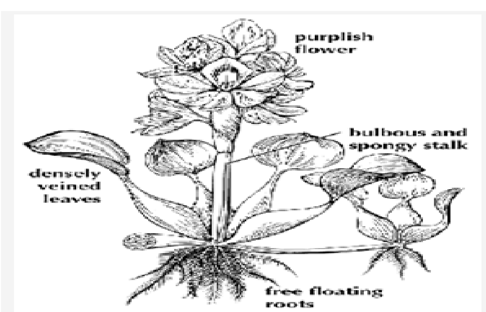

Figure.1 Morphology of Water Hyacinth

At first these new rosettes are attached to mother plant but stolons are very fragile so they could easily broken enabling young individuals to float away and colonies new areas. Only ten plants in just eight months could produce a population of 655,330 individuals.

Water hyacinth is mainly reproduced by generative means in its natural habitat and it produces large number of seeds. The flowering period lasts for about fifteen days. When flowering cycle ends flower stalk bends and the spike go under the water surface and seeds are released directly into the water. Each inflorescence contains normally 1 to 20 seed capsules and capsule caries 3 to 250 seeds. In spite of the production of this large number of seeds there are only 3 to 3.4 seeds per plant each year that could eventually able to germinate.

B. Ecological Factors

The environmentally-sound attribute of ecological technology is its capability of resource recovery and reuse. For instance, nutrients in nitrogenous and phosphorous wastewater compounds are recycled into usable biomass by means of the ecological food chains functioning in aquatic ecosystems "Ref. [19]".

Water hyacinth could grow best in warm waters rich in macronutrients. Optimal water pH for the growth of this aquatic plant is neutral but it could tolerate pH values from 4 to 10. This important characteristic enables *E.crassipes* to treat different types of wastewater .Optimal water temperature for growth is 28-30^{o}C. Temperatures above 33^{o}C inhibit further growth. Optimal air temperature is 21-30^{o}C. So if aquatic systems with water hyacinth are constructed in colder climates it would be necessary to build greenhouses for maintaining optimal temperature for plant growth and development. Low air humidity from 15% to 40% could also be a limiting factor for undisturbed growth of water hyacinth. *E.crassipes* tolerates drought well because it could survive in moist sediments up to several months.

C. Effects Of Heavy Metals

Some heavy metals have bio-importance as trace elements but, the biotoxic effects of many of them in human biochemistry are of great concern . The term "heavy metals" refers to any metallic element that has a relatively high density and is toxic or poisonous even at low concentration. To a small extent, they enter the body system through food, air, and water and bio-accumulate over a period of time "Ref. [10]".

Heavy metals include lead (*Pb*), cadmium (*Cd*), zinc (*Zn*),mercury (*Hg*), arsenic (*As*), silver (*Ag*) chromium (*Cr*),copper (*Cu*) iron (*Fe*), and the platinum group elements "Ref. [11]". If the concentration of heavy metals exceeds their limits in the drinking water, it can affect the human health. Earlier experiments showed that at higher doses they can cause anemia, liver and kidney damage and can even damage circulatory and nervous systems "Ref. [7]". The removal of heavy metals from aqueous solutions has therefore received considerable attention in recent years "Ref. [12]".

D. Mechanisms of Waste Water Treatment Using Water Hyacinth

Aquatic macrophytes like water hyacinth uptake contaminants and stores in its biomass. These plants are called bioaccumulators as they accumulate the contaminants in their tissues "Ref. [5]". They have high tolerance against contaminants like heavy metals and are able to absorb large quantities. This method of extracting heavy metal from

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polluted water bodies is called phytoextraction . The uptake of contaminants is by three methods

- Root absorption- The roots absorb water together with the contaminants in water. The presence of carboxyl · groups at the roots system induces a significant cation exchange through cell membrane and this might be the mechanism of moving heavy metal in the roots system where active absorption takes place. In sewage systems, the root structures of water hyacinth (and other aquatic plants) provide a suitable environment for aerobic bacteria to function. Aerobic bacteria feed on nutrients and produce inorganic compounds which in turn provide food for the plants. The plants grow quickly and can be harvested to provide rich and valuable compost. Water hyacinth has also been used for the removal or reduction of nutrients, heavy metals, organic compounds and pathogens from water.
- Foliar absorption- In addition to root absorption, plants could also derive low amounts of some contaminants through foliar absorption. They are passively absorbed through stoma cells and cracks in cuticle.
- Adsorption- The fibrous and feathery roots not only trap suspended solids and bacteria, but provide attachment sites for bacterial and fungal growth. The contaminants get adsorbed to the root surface by the bacteria present there. It is also due to ionic imbalance across the cell membrane.

IV. Experrimental Set Up

Water hyacinth was collected from three different local ponds. The experiments were conducted in tank as well as in jars. This was done in order to find out the efficiency of the plant in removing the pollutants when they were used as a single plant in jars and also when they are used collectively in tanks.

A. *Water Hyacinth grown in Tank*

A natural wetland was simulated in an RCC tank in which the water hyacinth was grown. A tank of size 3m x 2.5m x 1m having a capacity of 7.5m^3 was constructed. The tank was filled with 6000 litres of water. Then the water hyacinths collected were grown in the tank.

Figure 2: Water Hyacinth grown in tank

B. *Water Hyacinth grown in Jars*

Eight quart size jars were filled with 1litre of water containing chromium (1*ppm*) and copper (5*ppm*).The jars with chromium and copper were then sorted separately into four treatments with two jars in each treatment. The samples collected were placed in three of the four treatments and two jars were without plant as control as shown in "Fig. 3" & "Fig.4".

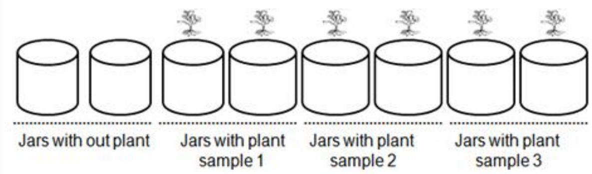

Figure 3: Experimental set up

The standard procedure was carried out with known concentrations of chromium and copper. The change in *pH*, *TDS*, *B.O.D*, Cr and *Cu* concentrations were found out at regular intervals using *APHA* methods "Ref. [1]".

Figure 4: The laboratory experimental set up

V. Results And Discussions

The experimental results of various tests conducted are shown below:

TABLE I
CHARACTERISTICS OF WATER SAMPLE COLLECTED FOR THE EXPERIMENT

pH	TDS (*mg/l*)	B.O.D (*mg/l*)	Cu(*ppm*)	Cr (*ppm*)
7.6	89	4	0.08	0.03

The results given in Table: 1 showed that the quality of the water sample collected is within the *W.H.O* standards "Ref. [2]". So the study was carried out by adding known concentrations of heavy metal ie; 1ppm of *Cr and* 5 ppm of *Cu*.

A. *Results of the experiments carried out with Chromium in the tank*

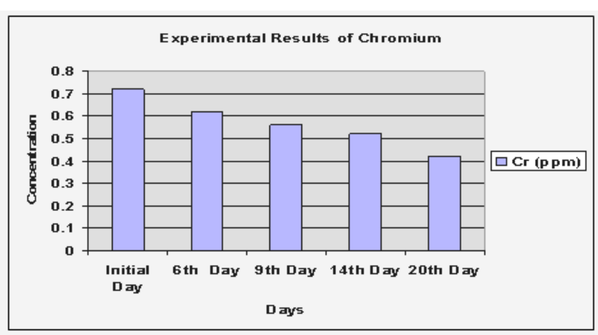

Figure.5: Variation of chromium concentration in the tank

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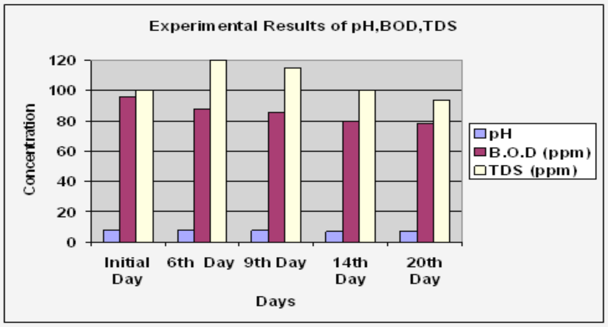

Figure.6: Variation of pH, BOD, TDS in the tank

B. Results of Copper in tank

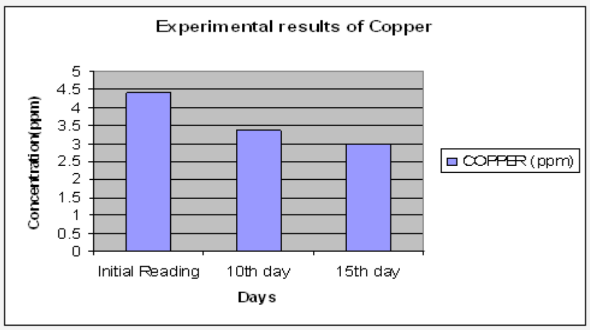

Figure.7: Variation of Copper concentration in the tank

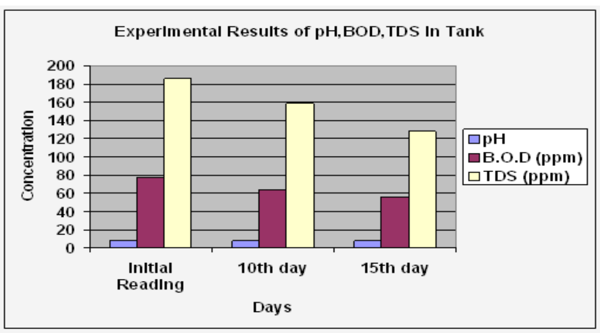

Figure.8: Results of pH, BOD,TDS in Tank

C .Results of experiments carried out in Jars with Chromium

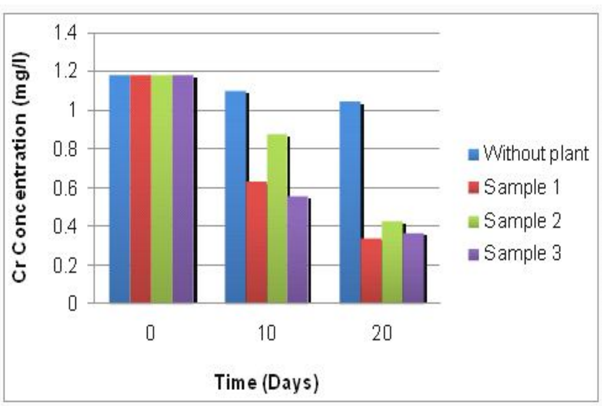

Figure.9: Results of Chromium

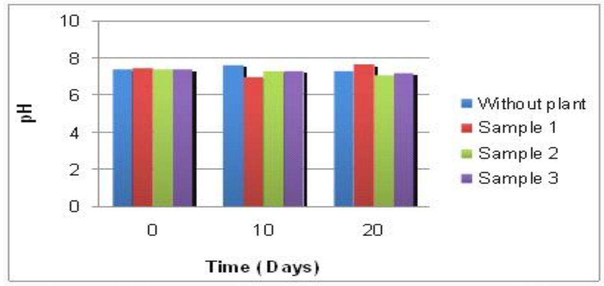

Figure.10: Results of pH

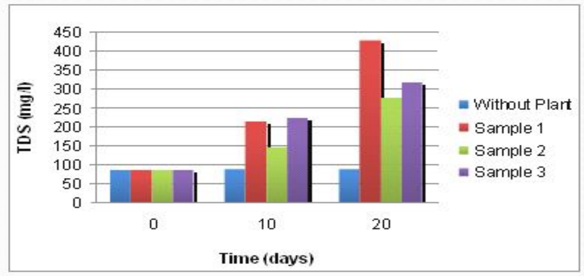

Figure.11 Results of TDS

D. Results of experiments carried out in Jars with Copper

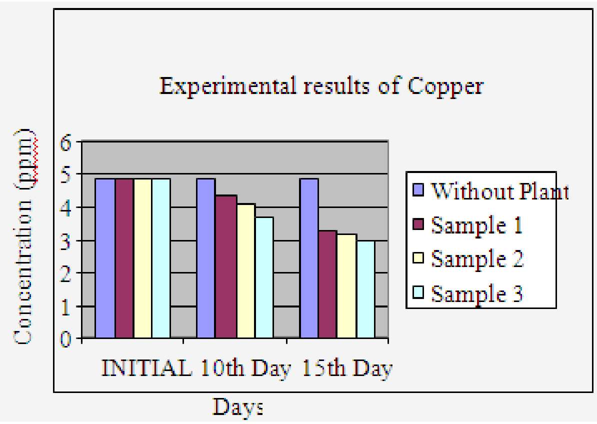

Figure.12: Results of Copper in Jars

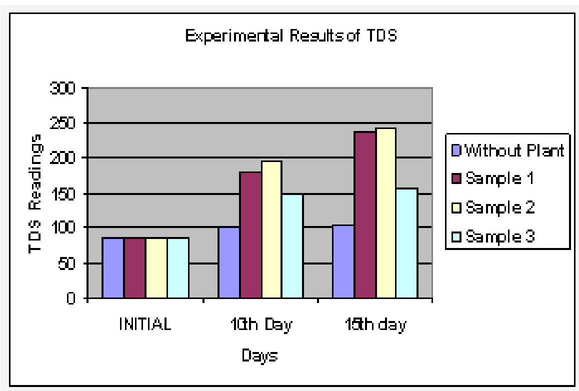

Figure.13:Results of TDS

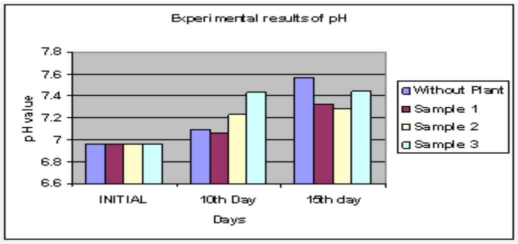

Figure.14: Results of pH

E .Discussions

The results of the experiments carried out in the tank showed that the plant has the ability to absorb heavy metals Chromium and copper from the waste water .The TDS values increased on placing the plants in the tank .This increase was due to the presence of clay or other fine particles present in the plant roots. On subsequent days it showed that the TDS value considerably decreased by the accumulation process of water hyacinth. There was reduction in BOD also. The jars with plant showed a considerable decrease in *Cr and Cu* concentrations. For jars without plant, the decrease of chromium and copper concentration was found to be very less .Thus we could conclude that loss due to evaporation and settlement were very less. There was no much change for *pH*. The *pH* value was found to be between 6 and 8. The value of *TDS* was found increasing. This might be attributed to the decay of the single plant growing in the jar with high *Cr* concentrations contributing to *TDS* content. The results obtained indicated that water hyacinth could be used as an effective means for the removal of heavy metals from waste water if the same is used collectively as done in the RCC tank.

CONCLUSIONS

The efficiency of waste water treatment was expressed in terms of the variation in pH, biochemical Oxygen Demand (*BOD*), total Dissolved Solids (*TDS*) and heavy metals before and after treatment. When the plants were collectively grown, the removal of pollutants from the water was very high. The experimental results have shown that about 65% removal of heavy metals could be achieved by water hyacinth. The plants have also got the capacity to convert the accumulated biomass into biogas. This system of treatment was cost effective since cost of installation and maintenance was very low. This system could be provided alone or together with other systems used for treating waste water. In conclusion, the present investigation demonstrated the feasibility of adopting a “sustainable” and eco-friendly approach to sewage waste water treatment using aquatic plant *Eichhornia*. Since it was only a laboratory scale base - line study, further investigations should be carried out in future on a large scale particularly focusing on phyto-remediation and resource utilization.

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